Validation of AMSR-E Polar Ocean Products Using a Combination of Modeling and Field Observations

Annual Report
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1. Project Overview

The goal of this effort is to complement and enhance the EOS Science Team's AMSR validation plan by combining additional detailed, *in situ* data collection with radiance modeling to evaluate products under a wide variety of weather and surface conditions. Our work includes surface data collection at scales relevant for remote sensing validation, detailed mapping of surface and atmospheric conditions using piloted aircraft and Unpiloted Airborne Vehicles (UAVs), and use of radiative transfer modeling to assess algorithm performance in the polar regions for the following standard products: sea ice concentration, sea ice temperature, and snow depth on sea ice. The resulting error assessment and statistics will address new product applications such as data assimilation, climate model evaluation, and model boundary conditions that require greater understanding of the magnitudes and physical sources of errors. The data and results will also provide input needed for algorithm adjustments and enhancements to optimize the AMSR products.

2. Summary of Work to Date

Activities during the previous year focused on three areas: (1) preparation and execution of a pilot in-situ measurement campaign near Barrow, Alaska; (2) refinement and testing of microwave radiative transfer models for ice, snow and atmosphere, (3) preparation for the intensive validation campaign in March 2003; and (4) initial examination of preliminary AMSR-E products. Main achievements include:

- Successful completion of the 2002 pilot field measurement campaign.
- Readiness for the intensive field effort in March 2003.
- Model development and sensitivity studies investigating the effects of snow conditions on sea ice algorithm performance.
- Preliminary conclusions regarding the information content and consistency of early AMSR-E brightness temperatures and sea ice products.

2.1 Spring 2002 Pilot Field Project

The original proposal included funding for a spring 2002 field effort. Due to delays in the Aqua launch and to accommodate requested budget cuts, the scope of this Year 1 field project was reduced significantly. However, given the range of issues involved in carrying out a successful Arctic field campaign, the investigators decided that a pilot effort was necessary prior to the intensive spring 2003 validation effort. Of particular importance was assuring that field methods were sufficiently defined and tested so that the one-time opportunity to acquire data in conjunction with the NASA P-3 flights would be exploited as effectively as possible.

Objectives for this pilot project included:

- Gain a better understanding of the range of ice conditions accessible from Barrow, and amount of effort required to sample different ice conditions.
- Develop and refine field methods, including measurement strategies and approaches for mapping and data recording.
- Determine what measurements are feasible, and under what conditions.
- Test performance of existing instruments and determine the need for additional instruments.
- Determine what approaches will need to be taken to assure collection of useful combined suites of NASA aircraft, surface, and Aerosonde data.

During May 2002, a crew of five individuals under the direction of co-PI M. Sturm planned and carried out a suite of measurements and reconnaissance on shore-fast ice in the Barrow, Alaska vicinity. Overall, the pilot project was successful in addressing each of these objectives, and established a solid foundation for the spring 2003 effort. Details of the 2002 field experiment can be found at http://polarbear.colorado.edu/AMSRICE/Barrow_02_summary2.html. The field project web site, containing additional information, plans and a photo gallery is located at http://polarbear.colorado.edu/AMSRICE/AMSRIce03.html

Main findings were:

- A considerable range of ice and snow conditions were found within relatively easy access of Barrow.
- The dimensions of these features, as expected, are not sufficient to serve as AMSR pure-pixel targets, but in most cases should be sufficient to provide targets for NASA P-3 imaging using the Polarimetric Scanning Radiometer (PSR) microwave instrument (http://www1.etl.noaa.gov/radiom/psr/) on the plane.
- We were able to operate fairly easily in a variety of ice conditions, and carried out a thorough set of measurements without major problems.
- A variety of methods for mapping surface properties and variability were defined, such as procedures for sampling snow properties, snow/ice temperatures, and spatial variability.

2.2 March 2003 Field Experiment

Considerable effort during the past year was expended on planning for the project-centerpiece 2003 field experiment in conjunction with NASA P-3 flights. The field portion of the spring validation effort (“AMSRIce03”) builds upon the pilot experiment summarized above. Planning activities included:

- Monitoring of fast ice formation through the autumn and winter, including mapping and analysis of SAR imagery to delineate ice conditions in the Barrow area.
- Assembly of a geographic information system data base for the Barrow field location.
- Submission of requests for remote sensing support, including obtaining RADARSAT SAR images from the Alaska SAR Facility and requesting acquisition of quick-look SAR imagery during the field experiment period (3-21 March 2003).
- Obtaining permits and permissions from local North Slope Borough agencies and from the U.S. Fish and Wildlife Service.
- Providing information notices to Barrow and North Slope Borough groups and arranging for participation by a local ice expert and guide.

- Assessment of performance characteristics of NASA P-3 instrumentation in terms of expected ice conditions (e.g., footprint sizes and scanning rates of the PSR relative to dimensions of ice features, etc.).
- Preparation of flight line maps for the NASA P-3, including consideration of local impacts (Figure 1).
- Coordination with Aerosonde, Ltd. for supporting Aerosonde UAV flights.
- Field crew preparation and training.
- Construction of field equipment, including a sled platform for infrared and microwave radiometers and a heated sled-mounted shelter.
- Assembly and shipping of equipment to Barrow.
- Weekly teleconference calls (mid-January – February) with NASA personnel for planning.
- Planning for participation in a U.S. Navy ice camp scheduled for deployment in mid-March in the Beaufort Sea.
- Coordination with GHCC and NSIDC for provision of subsets of AMSR-E preliminary data for use during the field effort.

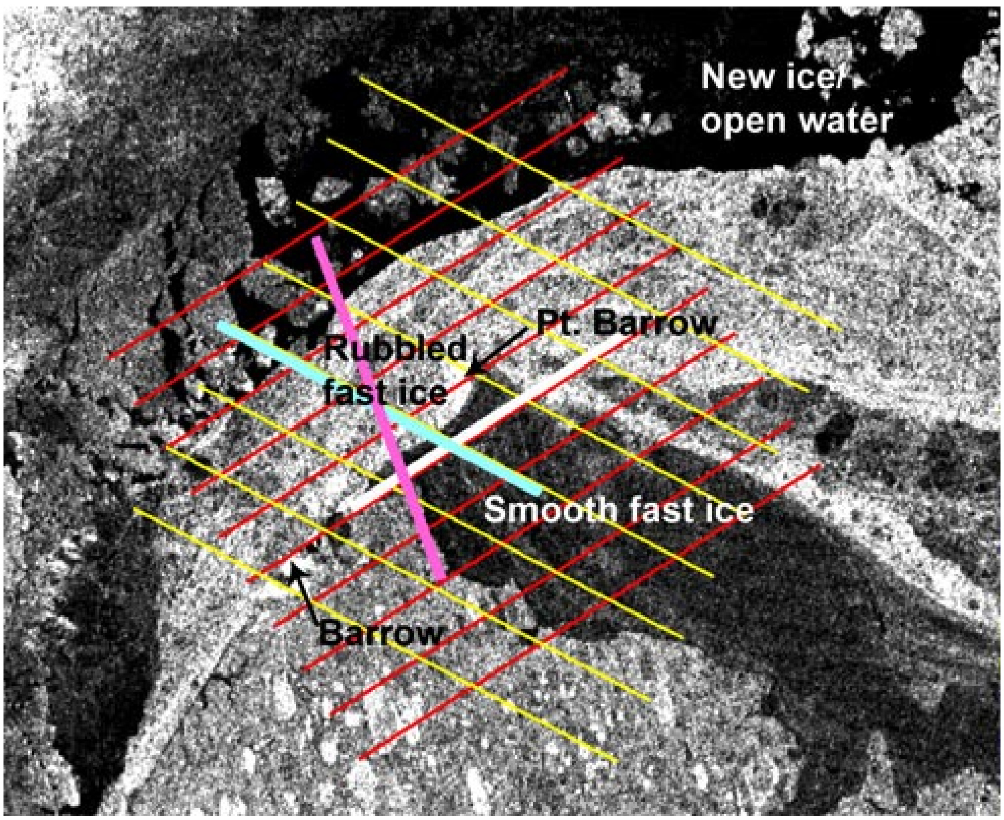

Figure 1. Preliminary flight plan for the NASA P-3 over the Barrow-area field site. Flight lines at 5000 ft. [yellow], 3500 ft. [red], and 500 ft. [white, blue and fuchsia] are overlain onto a RADARSAT SAR image. The locations of the village of Barrow and Point Barrow are indicated, as are different sea ice conditions (image courtesy RADARSAT International).

One of the key tasks to date for the field planning has been to track the formation and variability of sea ice in the Barrow area. Following the formation history of the shore-fast ice zone allows us to determine which areas are likely to be most stable and safe for the on-ice work and which locations are best for P-3 overpasses. This history also helps in determining relationships between microwave emissivity and ice age, type and condition (Figure 2).

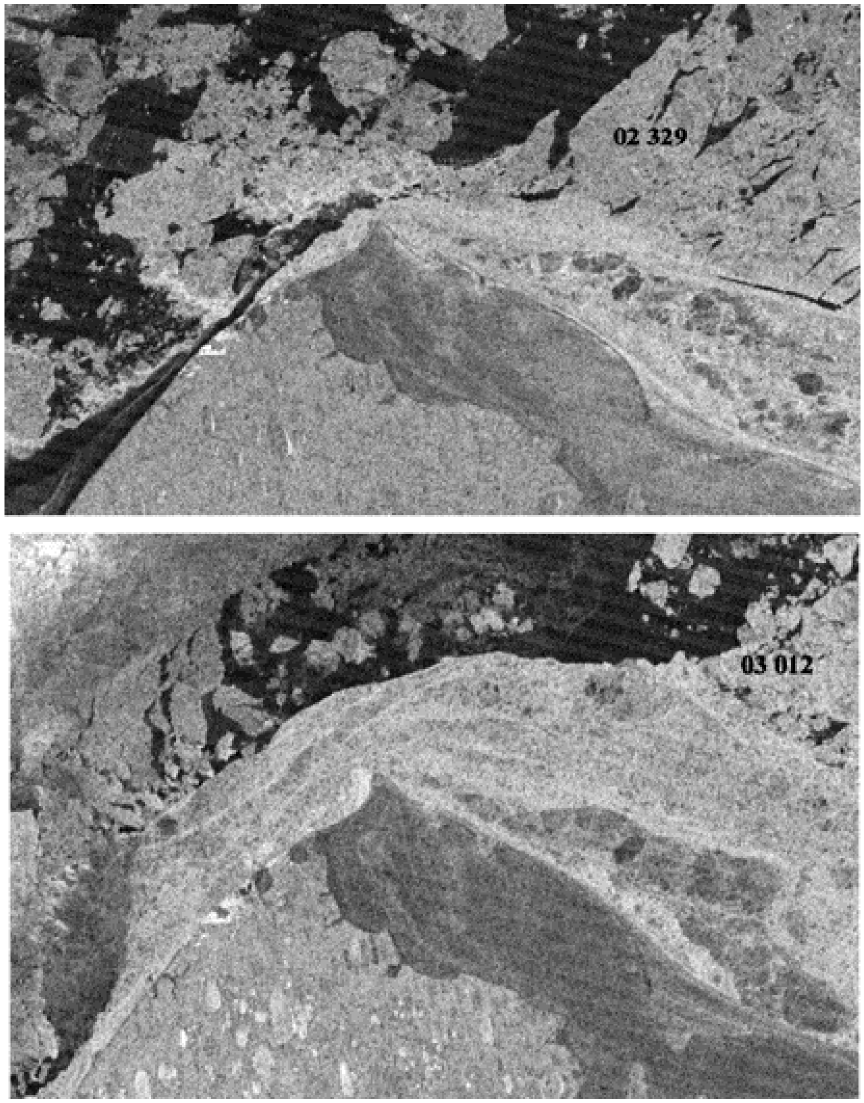

Figure 2. RADARSAT images for 25 November 2002 (top) and 12 January 2003 (bottom). The image sequence shows areas of ice that have remained relatively stable from November through January. Point Barrow is located approximately in the center of the images. See Figure 1 for location and ice labels. (Images courtesy RADARSAT International).

2.3 Supplemental Field Effort

Recognizing that budget limitations have restricted the scope of this project considerably, and that the validation effort has the potential to provide a wider science benefit, an expansion of the March 2003 field campaign for validation of the AMSR-E polar ocean products was proposed to the NASA Cryospheric Processes Program. This additional project "An Expanded Field Validation Campaign for AMSR-E Polar Ocean Products Using a Combination of Modeling and Field Observations" by M. Sturm, D. Perovich, J. Richter-Menge and T. Tucker, was peer reviewed and accepted for funding in November, 2002. This additional effort provides for: 1) aerial photography mapping of the sea ice field area near Barrow in the week prior to the arrival of the NASA P-3 aircraft, 2) increasing the size and experience of the field team in order to collect a more extensive set of snow and ice measurements, 3) meshing the field measurement effort with GPS-based mapping to facilitate extrapolation and interpolation of field results to airborne sensor footprint size, and 4) adding ground-based measurements of microwave emissivity to complement the aircraft and satellite measurements.

As part of AMSRIce03, this additional funding will result in the collection of coincident surface-based passive microwave data that will help bridge the gap between the detailed surface measurements and the P-3 PSR observations, and will provide comparison data for model calculations. The funding will also allow us to take advantage of the Navy ice camp noted above, which represents a significant expansion of the types of ice conditions to be sampled. The P-3 will carry out one flight over the camp, coincident with our field measurements and with Aerosondes to provide atmospheric column data as well as skin temperatures and aerial photographs acquired at low altitude.

2.4 Modeling

As noted above, microwave modeling provides a means of extending the validation effort beyond the direct comparison of observations. Modeling activities to date include: (1) revision and testing of two microwave radiative transfer models (MWMOD and MEMLS) and (2) sensitivity tests of snow effects on sea ice algorithm performance. MWMOD (MicroWave MODel; Fuhrhop et al.,1997) is designed to estimate top-of-the-atmosphere radiances in microwave frequencies as emitted from a sea ice or open water surface and modified by an atmospheric column. MEMLS (Microwave Emission Model of Layered Snowpacks; Wiesmann and Maetzler, 1998, 1999) simulates emission from snow layers as a function of thickness, density and grain characteristics. The goal for the first year was to set up the models (MWMOD and MEMLS) so that in-situ data from the Arctic 2003 field campaign can be utilized.

Since emission from sea ice involves ice, snowpack and atmosphere, we are working to couple MWMOD and MEMLS. Our approach consists of simulating emission from the ice column using MWMOD, then supplying this brightness temperature to MEMLS in place of the normal "soil" layer assumed by MEMLS. The top-of-snowpack brightness temperature simulated by MEMLS with these inputs is then supplied as the surface temperature to MWMOD, which then proceeds to calculate the effects of the atmosphere. This approach allows us to treat the ice, snow and atmosphere as a complete column, and should serve as a useful tool for assessing the magnitudes and relative importance of different factors on algorithm performance. We initially investigated recoding MEMLS (written in MATLAB) or MWMOD (Fortran) to merge the two models into a single code, but we concluded that the effort required to combine the models was not appropriate for our needs as part of this project.

Because of the lack of sufficient in-situ data of snow physical properties (e.g. grain size, density, etc) the current AMSR-E snow depth on sea ice algorithm does not account for variations of these parameters. A key goal of the modeling portion of our work is to assess quantitatively the errors that result from changes in snow and ice properties. Initial sensitivity studies to investigate snow effects are summarized below.

MEMLS is particularly useful for this purpose because of the generally layered nature of snow on sea ice. Simulations described here were done using a typical winter snow profile with a total snow depth of 23cm (as provided by Dr. Robert Massom, Antarctic CRC, Hobart, Australia). A common feature of this profile is thin ice layers between the different layers of snow. In order to investigate the importance of these layers to the microwave signal we simulated a snow cover that consists of a varying number of layers of snow (each with a depth of 5cm) that are interspersed with ice layers with a thickness of 1cm. The snow layers had variable physical properties, including a range of grain sizes and densities. One input parameter for MEMLS is the correlation length. Since grain size rather than correlation length is typically measured from snow profiles, it was necessary to first convert the grain size to correlation length using formulae from Maetzler (2002).

Calculations of emissivities versus frequency for different snow depths (including icy layers) show that the emissivities are generally reduced with increasing frequency as a result of scattering. The largest gradient occurs between 20 and 40 GHz, which is significant since the 36 GHz channel is used for the AMSR snow depth on sea ice algorithm. At higher frequencies differences are small for deeper snow because of the decreasing penetration depth with increasing frequency. Figure 3 illustrates the specific effect of ice layers on estimated snow depth over sea ice.

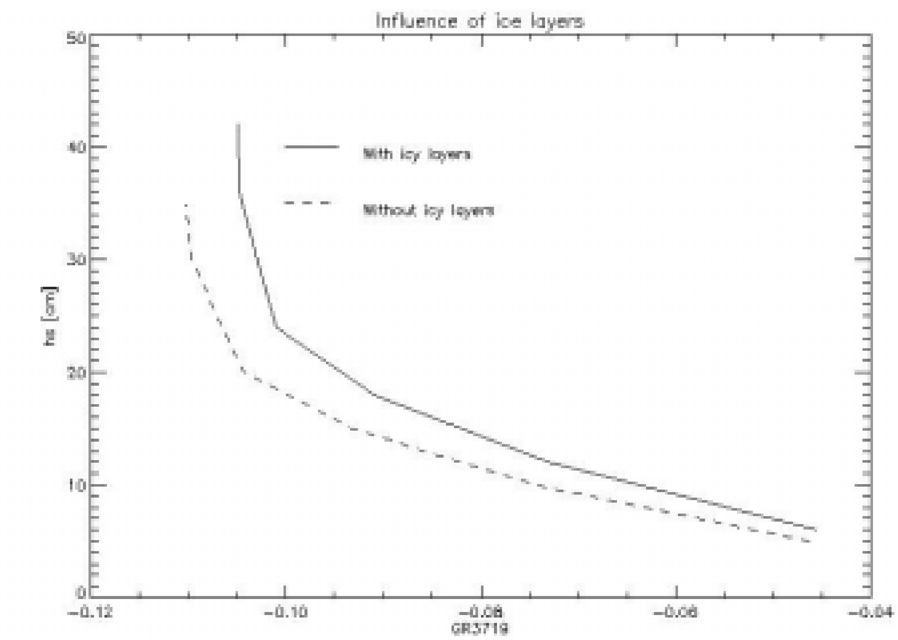

Figure 3. Effect of the presence of snow-pack ice layers on retrieval of snow depth over sea ice.
Additional model runs have been done with variations in grain size and density. Our results are similar to those seen in previous studies of the effects of snow conditions on snow-on-land algorithms, but they illustrate the effects with a sea-ice substrate. Model issues in need of improvement include determining the optimum way to compute snow/ice interface reflectivities, and developing a means of including a saline slush layer directly on top the snow/ice interface.

2.5 AMSR-E Analyses

Our analysis of actual AMSR-E data have, to date, considered basic issues such as assessing image quality and detail, examining the potential information content of the lower frequency channels, and studying areas where differences between NT2- and enhanced Bootstrap-derived ice concentrations are large. This work has been done initially with a small number of samples from the NASDA product stream, and more recently using data available from GHCC.

One of the most striking features of the AMSR-E data in terms of sea ice conditions is the considerable level of detail offered by the higher spatial resolution of AMSR versus SSM/I. This detail allows detection of specific ice features such as large leads and localized open water/thin ice areas (polynyas) (Figure 4).

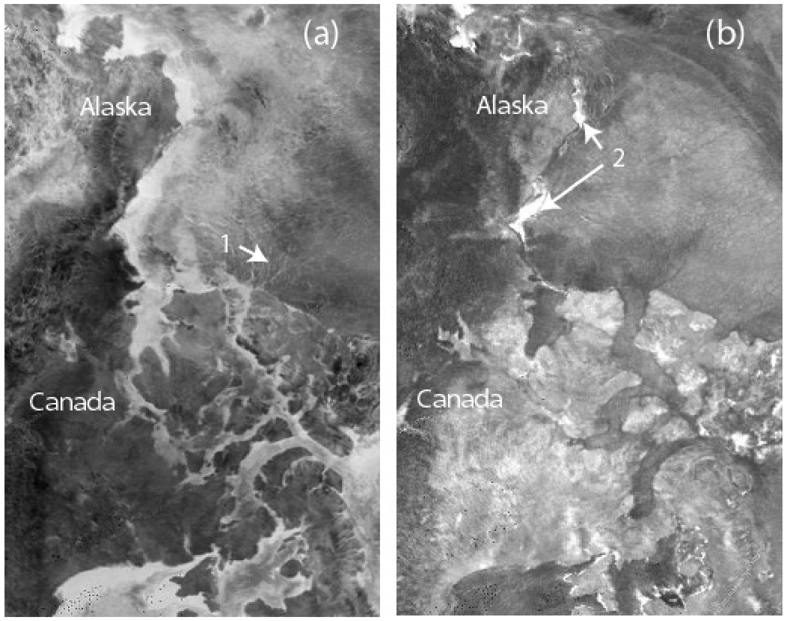

Figure 4. AMSR-E 89 GHz vertically polarized brightness temperatures (a) and polarization ratio of 89 GHz vertically and horizontally polarized channels (b) for the North American Arctic on 21 January 2003. Note the fine detail (relative to SSM/I) in these 6-km resolution data, such as the lead complex extending to the west of Banks Island (location 1 in [a]) and the open water/thin ice polynyas at location 2 in (b). These images have been enhanced using a spatial filter to highlight detail and contrast. Note that the polynyas along the northern tip of Alaska correspond to the open water/thin ice area seen in the RADARSAT image seen in Figure 3.

Initial comparisons of ice concentrations derived from AMSR-E (using NT2 and enhanced Bootstrap algorithms) and SSM/I (using the NASA Team algorithm) point out the additional information provided by the AMSR-E resolution, as well as some significant features of interest, including areas where differences are relatively large between AMSR-E and SSM/I concentrations and between AMSR-E NT2 and bootstrap concentrations (e.g., Figure 5). We intend to use such comparisons to help direct the P-3 to regions where differences exist so that the source of differences can be determined. Similar conparisons will be undertaken using NT, NT2 and enhanced bootstrap algorithms applied to PSR data over the Barrow area where field measurements are available to help quantify the effects of ice, snow and atmosphere on algorithm performance.

3. Plans

Major tasks for the next project year include:

- Completion of the AMSRIce03 field campaign.
- Processing, summarizing and documenting AMSRIce03 data sets.
- Delivery of AMSRIce03 data sets and documentation to NSIDC for archival.
- Assembly of supporting data sets from the Barrow CMDL and DOE ARM sites.
- Model testing and refinement using the in-situ snow, ice, atmosphere and microwave emission data.
- Comparison of PSR brightness temperatures and PSR-based sea ice algorithm products to the AMSRIce03 field observations.

- Quantifying the influences of ice, snow, atmosphere and land boundary conditions on PSR products.
- Intercomparisons of SAR, aircraft, and AMSR-E imagery.
- Assessment of product consistency between SSM/I- and AMSR-derived ice concentration data.
- Extension of the modeling effort to study conditions not included within the direct measurement campaign.

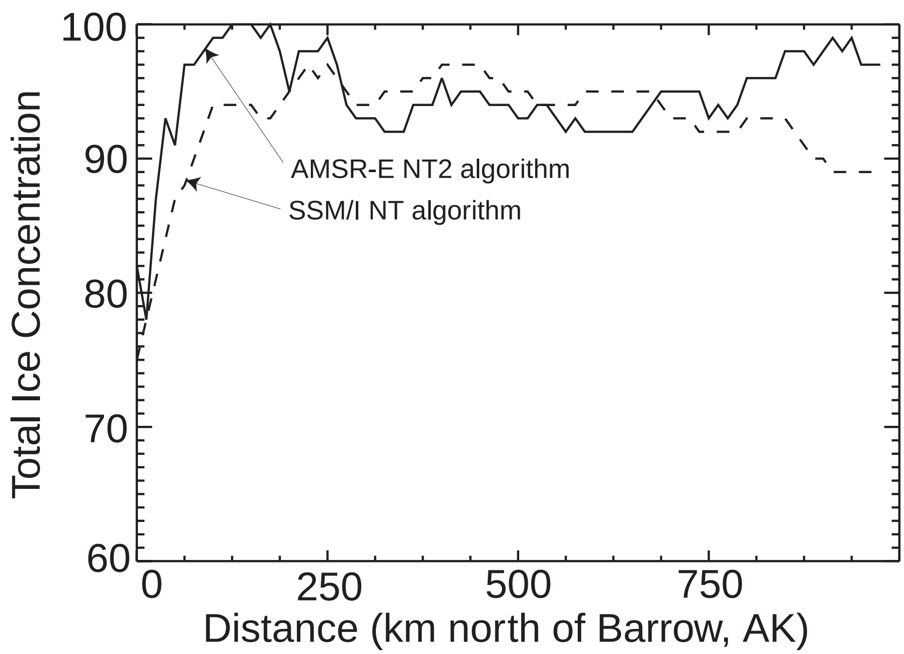

Figure 5. Comparison of total sea ice concentrations (daily mean for 21 January 2003) derived from AMSR-E data using the NT2 algorithm and from SSM/I using the NT algorithm. As seen in previous analyses, the NT2 algorithm tends to yield higher ice concentrations than NT. Similar comparisons are planned with the NT algorithm applied to the AMSR-E data to determine effects of instrument versus algorithm on such differences.

4. References

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